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A SYSTEM APPROACH TO NAVY MEDICAL EDUCATION AND TRAINING, APPEN--ETC(U)
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APPENDIX 27.

COMPETENCY CURRICULUM FOR NUCLEAR MEDICINE TECHNICIAN

APPLICATION OF A SYSTEM APPROACH
U.S. NAVY MEDICAL DEPARTMENT
EDUCATION AND TRAINING PROGRAMS
FINAL REPORT

Prepared under Contract to
OFFICE OF NAVAL RESEARCH
U.S. DEPARTMENT OF THE NAVY

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The study objective consisted of a determination of what the health care personnel in the Navy's Medical Department, Bureau of Medicine and Surgery actually do in their occupations; improving the personnel process (education and training); and building a viable career pathway for all health care personnel. Clearly the first task was to develop a system of job analyses applicable to all system wide health care manpower tasks. A means of postulating simplified occupational clusters covering some 50

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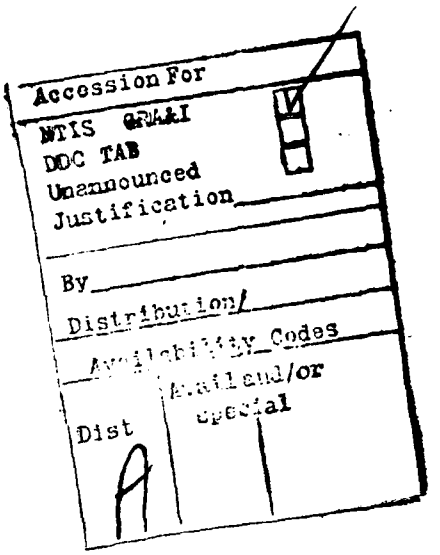
currently designated Navy enlisted occupations, 20 Naval Enlisted Classification Codes (NEC's) were computerized. A set of 16 groupings that cover all designated occupations was developed so as to enhance the effectiveness of professionals and sub-professionals alike.



FOREWORD

The project, "Application of a System Approach to the Navy Medical Department Education and Training Programs," was initiated in May of 1969 as a realistic, comprehensive response to certain objectives set forth in ADO 43-03X, and to memoranda from both the Secretary of Defense and the Assistant Secretary of Defense, Manpower and Reserve Affairs. The Secretary's concern was stated in his memorandum of 29 June 1965, "Innovation in Defense Training and Education." More specific concerns were stated in the Assistant Secretary's memorandum of 14 June 1968, "Application of a System Approach in the Development and Management of Training Courses." In this he called for "vigorous and imaginative effort," and an approach "characterized by an organized training program with precise goals and defined operational interrelation among instructional system components." He also noted, "Job analyses with task descriptions expressed in behavioristic terms are basic and essential to the development of precise training goals and learning objectives."

The Project

System survey and analysis was conducted relative to all factors affecting education and training programs. Subsequently, a job-analysis sub-system was defined and developed incorporating a series of task inventories ". . . expressed in behavioristic terms . . ." These inventories enabled the gathering of job activity data from enlisted job incumbents, and data relating to task sharing and delegation from officers of the Medical, Nurse and Dental Corps. A data management sub-system was devised to process incumbent data, then carry out needed analyses. The development of initial competency curricula based upon job analysis was implemented to a level of methodology determination. These methods and curriculum materials constituted a third (instructional) sub-system.

Thus, as originally proposed, a system capability has been developed in fulfillment of expressed needs. The system, however, remains untested and unevaluated. ADO 43-03X called for feasibility test and cost-effectiveness determination. The project was designed to so comply. Test and evaluation through the process of implementation has not proved feasible in the Navy Medical Department within the duration of the project. As designed and developed the system does have " . . . precise goals and defined operational interrelation among instructional system components." The latter has been achieved in terms of a recommended career structure affording productive, rewarding manpower utilization which bridges manpower training and health care delivery functions.

Data Management Sub-System

Job analysis, involving the application of comprehensive task inventories to thousands of job incumbents, generates many millions of discrete bits of response data. They can be processed and manipulated only by high speed computer capability using rigorously designed specialty programs. In addition to numerical data base handling, there is the problem of rapidly and accurately manipulating a task statement data base exceeding ten thousand carefully phrased behavioral statements. Through the use of special programs, task inventories are prepared, printouts for special purposes are created following a job analysis application, access and retrieval of both data and tasks are efficiently and accurately carried out, and special data analyses conducted. The collective programs, techniques and procedures comprising this sub-system are referred to as the Navy Occupational Data Analysis Language (NODAL).

Job Analysis Sub-System

Some twenty task inventory booklets (and associated) response booklets) were the instruments used to obtain job incumbent response data for more than fifty occupations. An inventory booklet contains instructions, formatted questions concerning respondent information ("bio-data"), response dimension definitions, and a list of tasks which may vary in number from a few hundred to more than a thousand per occupational field.

By applying NODAL and its associated indexing techniques, it is possible to assemble modified or completely different inventories than those used in this research. Present inventories were applied about three years ago. While they have been rendered in operational format, they should not be reapplied until their task content is updated.

Response booklets were designed in OPSCAN mode for ease of recording and processing responses.

Overall job analysis objectives and a plan of administration were established prior to inventory preparation, including the setting of provisional sample target sizes. Since overall data attrition was forecast to approximate twenty percent, final sample and sub-sample sizes were adjusted accordingly. Stratified random sampling techniques were used. Variables selected (such as rating, NEC, environment) determined stratifications, together with sub-population sizes. About fifteen percent of large sub-populations were sought while a majority of all members of small sub-populations were sought.

Administration procedures were established with great care for every step of the data collecting process, and were coordinated with sampling and data analysis plans. Once set, the procedures were formalized as a protocol and followed rigorously.

Instructional Sub-System

Partial "competency curricula" have been composed as an integral sub-system bridging what is required as performance on the job with what is, accordingly, necessary instruction in the training process. Further, curriculum materials were developed to meet essential requirements for implementing the system so that the system could be tested and evaluated for cost effectiveness. However, due to the fact that test and evaluation was not feasible in the Navy Medical Department within the duration of the project, it was not possible to complete the development of the system through the test and evaluation phase. The inability to complete this phase also interrupted the planned process for fully developing the curricula; therefore, instead of completed curricula ready for use in the system, the curricula were partially developed to establish the necessary sub-system methodology. The competency curricula are based on tasks currently performed by job incumbents in 1971. (The currency of a given curriculum depends upon periodic analysis of incumbents' jobs, and its quality control resides in the evaluation of the performance competency of the program's graduates.)

A competency curriculum provides a planned course of instruction or training program made up of sequenced competency units which are, in turn, comprised of sequenced modules. These modules, emphasizing performance objectives, are the foundation of the curriculum.

A complete module would be comprised of seven parts: a cluster of related tasks; a performance objective; a list of knowledges and skills implied by the objective; a list of instructional strategies for presenting the knowledges and skills to the learner; an inventory of training aids for supporting the instructional strategies; a list of examination modes; and a statement of the required training time. In this project, curriculum materials have been developed to various levels of adequacy, and usually comprise only the first three parts; the latter four need to be prepared by the user.

The performance objective, which is the most crucial part of the module, is the basis for determining curriculum content. It is composed of five essential elements: the stimulus which initiates the behavior; the behavior; the conditions under which the behavior takes place; the criteria for evaluating the behavior; and the consequence or results of the behavior. A sixth element, namely next action, is not essential; however, it is intended to provide linkage for the next behavior.

Knowledges and skills listed in the module are those needed by the learner for meeting the requirements of the performance objective.

Instructional strategies, training aids, examination modes and training time have been specified only for the Basic Hospital Corps Curriculum. The strategies, aids and modes were selected on the basis of those considered to be most supportive in presenting the knowledges and skills so as to provide optimum learning effectiveness and training efficiency. The strategies extend from the classroom lecture as traditionally presented by a teacher to the more sophisticated mediated program for self-instruction. The training aids, like strategies, extend from the traditional references and handout material in the form of a student syllabus to mediated programs for self-instruction supported by anatomical models. Examination modes extend from the traditional paper and pencil tests to proficiency evaluation of program graduates on the job, commonly known as feedback. Feedback is essential for determining learning effectiveness and for quality control of a training program. The kind of instructional strategies, training aids and examination modes utilized for training are limited only by such factors as staff capability and training budget.

The training time specified in the Basic Hospital Corps Curriculum is estimated, based upon essential knowledge and skills and program sequence.

The competency curriculum module, when complete, provides all of the requirements for training a learner to perform the tasks set forth in the module. A module may be used independently or related modules may be re-sequenced into modified competency units to provide training for a specific job segment.

Since the curricula are based upon tasks performed by job incumbents in 1971, current analysis of jobs needs to be accomplished using task inventories that have been updated to reflect changes in performed tasks. Subsequent to job analysis, a revision of the curricula should be accomplished to reflect task changes. When the foregoing are accomplished, then faculty and other staff members may be indoctrinated to the competency curricula and to their relationship to the education and training system.

In addition to the primary use for the systematic training of job incumbents, these curricula may be used to plan for new training programs, develop new curricula, and revise existing curricula; develop or modify performance standards; develop or modify proficiency examinations; define billets; credentialize training programs; counsel on careers; select students; and identify and select faculty.

The System

Three sub-systems, as described, comprise the proposed system for Education and Training Programs in the Navy Medical Department. This exploratory and advanced developmental research has established an overall methodology for improved education and training incorporating every possible means of providing bases for demonstrating feasibility and cost effectiveness. There remains only job analysis sub-system up-dating, instructional sub-system completion, and full system test and evaluation.

Acknowledgements

The authors wish to acknowledge the invaluable participation of the several thousands of Naval personnel who served as respondents in inventory application. The many military and civilian personnel who contributed to developmental efforts are cited by name in the Final Report.

The authors also wish to acknowledge former colleagues for singularly important contributions, namely, Elias H. Porter, Ph.D., Carole K. Kauffman, R.N., M.P.H., Mary Kay Munday, B.S.N., R.N., Gail Zarren, M.S.W., and Renee Schick, B.A.

Identity and acknowledgement of the project Advisory Group during the project's final year is recorded in the Final Report.

Lastly, the project could not have been commenced nor carried out without the vision, guidance and outstanding direction of Ouida C. Upchurch, Capt., NC, USN, Project Manager.

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COMPETENCY CURRICULUM FOR

NUCLEAR MEDICINE TECHNICIAN

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT I: INSTRUMENT MAINTENANCE

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit I: Instrument Maintenance

MODULE 1: INSTRUMENT RELIABILITY

TASKS

a. Determine energy resolution of gamma scintillation counter
b. Determine long-term instrument stability by daily counting of long-lived standard source
c. Determine short-term instrument reproducibility by repetitive counting of standard
d. Compute the statistic chi-squared to determine instrument reliability
e. Prepare and maintain instrument performance charts

PERFORMANCE OBJECTIVE

(Stimulus)	Routinely on schedule determined by laboratory supervisor and at request of supervisor
(Behavior)	The NMT will perform tests to assure that instruments are operating properly
(Conditions)	With indirect supervision; using appropriate standards of radioactive materials, graphic data, quality control charts, statistical tables
(Criteria)	Results are within ± 2 standard deviations of mean laboratory values
(Consequence)	An instrument is shown to be reliable, resulting in increased confidence in results obtained from it; aberrant behavior of instrument leads to required corrective maintenance
(Next Action)	Record results; report to supervisor that instrument performance is or is not acceptable

KNOWLEDGES AND SKILLS

Theory of operation of complete scintillation counting systems, fluors, photomultiplier tubes, amplifiers, scalers, rate meters, HV (high-voltage) supply
Decay schemes, gamma-ray spectra
Statistical tables for chi squared
Use and maintenance of quality control charts

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit I: Instrument Maintenance

MODULE 2: GAMMA SCINTILLATION COUNTER (IN VIVO AND IN VITRO) OPERATNG PARAMETERS

TASKS

a. Determine optimal operating voltage of scintillation counter
b. Perform energy calibration of single-channel analyzer
c. Determine energy resolution of counting system
d. Determine effects of source activity on counting rate
e. Determine instrument counting efficiency

PERFORMANCE OBJECTIVE

(Stimulus) Routinely in accordance with established laboratory quality control and preventive maintenance schedules or if instrument performance appears erratic

(Behavior) The NMT will perform tests to assure that the instrument is operating properly and that instrument parameters are correctly selected by operator

(Conditions) With indirect supervision; using appropriate standards of radioactive materials, graphic data, decay schemes, timers

(Criteria) Upon technical review by supervisor, instrument is verified to be operating properly

(Consequence) An instrument is shown to be reliable, resulting in increased confidence in the results of tests on humans performed with it

(Next Action) Record results; report to supervisor that instrument performance is acceptable or that instrument is in need of repair

KNOWLEDGES AND SKILLS

Theory of operation of complete scintillation counting systems, fluors, photomultiplier tubes, amplifiers, scalers, rate meters, high-voltage supply

Decay schemes, gamma-ray spectra obtained under various laboratory conditions related to source and detector

Relationship between source activity, geometry, intrinsic efficiency and counting rate

Statistical variability associated with random nature of decay of radionuclides

Use and maintenance of quality control charts
Methods of determining instrument dead time and/or counting losses, e.g., paired-source method, increasing activity method, decreasing activity (short half-life) method

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT II: INSTRUMENTATION IN VITRO

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit II: Instrumentation In Vitro

MODULE 1: LIQUID SCINTILLATION--OPERATING PARAMETERS

TASKS

a. Use liquid scintillation counter for internal sample counting
b. Prepare scintillation media for internal sample counting
c. Select voltage, gain and window width for various radionuclides
d. Make corrections for sample quenching
e. Determine counting efficiency for samples
f. Determine activity of samples counted

PERFORMANCE OBJECTIVE

(Stimulus)	On receipt of samples for assay or on request of supervisor
(Behavior)	The NMT will perform tests to determine proper instrument operating parameters for various radionuclides which are to be counted in the liquid scintillation counter
(Conditions)	With indirect supervision; using volumetric glassware, liquid radioactive standard sources, slide rules, calculators, graph paper
(Criteria)	Results are accepted on review by supervisor
(Consequence)	Constancy of reproductivity and accuracy of results of laboratory assays, assuring reliable results on which diagnosis can be based
(Next Action)	Record results; incorporate into standard laboratory procedure

KNOWLEDGES AND SKILLS

Theory and operation of liquid scintillation counter and multiple-channel analyzers (2 to 4 channels)
Statistics of radioactive decay
Theory of interaction of radiation with scintillation media and its effect on signal size distribution
Components and function of components of scintillation media
Modes of quenching (solute, color) and quenching agents
Sources of information on decay schemes for various radionuclides especially ^{3}H, ^{14}C, ^{35}S, ^{32}P, ^{45}Ca, ^{125}I, ^{52}Fe, and shape of the spectrum produced by such nuclides
Effects of temperature on performance of photomultiplier tubes
Preparation of graphs on linear paper

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit II: Instrumentation In Vitro

MODULE 2: IONIZATION CHAMBERS--OPERATING PARAMETERS

TASKS

a. Determine effects of sample volumes on counting rate
b. Determine optimum volume for sample counting
c. Prepare graphs or tables for volume corrections to be applied with various radionuclides
d. Determine calibration factors for radionuclides not provided by instrument manufacturer

PERFORMANCE OBJECTIVE

(Stimulus)	Upon receipt of request from supervisor
(Behavior)	The NMT will perform tests to determine the effects of varying sample volume on results obtained in assay of gamma-emitting radionuclides
(Conditions)	With indirect supervision; using test tubes, syringes, radioactive standard sources, graph paper, ionization chamber
(Criteria)	Results are accepted on review by supervisor
(Consequence)	Constancy and accuracy of results of laboratory assay, leading to correct dosage of radiopharmaceutical for patient
(Next Action)	Record results; incorporate into standard laboratory procedure

KNOWLEDGES AND SKILLS

Relationship between source activity and exposure dose rate (specific gamma-ray output)
Statistical variability associated with radioactive decay
Rates of radioactive decay associated with source(s) tested
Range of intensity over which instrument is reliable
Theory of operation of ionization chamber

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit II: Instrumentation In Vitro

MODULE 3: GAMMA SCINTILLATION--OPERATING PARAMETERS

TASKS

a. Determine effects of sample volume on counting rate
b. Determine optimum volume for sample counting
c. Prepare correction curves for samples of various volumes

PERFORMANCE OBJECTIVE

(Stimulus)	On request from supervisor
(Behavior)	The NMT will make tests to determine the influence of volume on efficiency of sample counting
(Conditions)	With indirect supervision; using test tubes, liquid solutions of radioactive materials, gamma scintillation counting equipment, graph paper
(Criteria)	Upon review of supervisor standard volumes for counting radioactive solutions are chosen
(Consequence)	Constancy of results of laboratory assays is maintained minimizing variability due to source configuration
(Next Action)	Record results; incorporate into standard laboratory procedures

KNOWLEDGES AND SKILLS

Relationship between source activity and counting rate
Statistical variability associated with random nature of radioactive decay
Rates of radioactive decay of standard source(s) used
Knowledge of instrument dead time or counting losses
Theory of operation of scintillation counter and single-channel analyzer

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT III: INSTRUMENTATION IN VIVO

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit III: Instrumentation In Vivo

MODULE 1: STATIONARY PROBE DEVICES

TASKS
a. Operate external detection probe
b. Select/insert proper collimator for quantitative/function studies
c. Operate dual-probe external detection system

PERFORMANCE OBJECTIVE

(Stimulus) Upon receipt of request for a specific test involving determination of gland or tissue activity
(Behavior) The NMT will prepare the instrument and perform the specific study requested by the physician
(Conditions) With indirect supervision; using local manuals
(Criteria) A technically adequate study as determined by supervisor; performed in accordance with standard laboratory operating procedures
(Consequence) Maximum information obtained from study for evaluation by physician; minimized radiation dose to patient
(Next Action) Transmit results of study to physician

KNOWLEDGES AND SKILLS

Complete operation of single-channel analyzer and scintillation counter
Handling of patients
Topographical anatomy
Principles of gamma-ray interactions in matter
Range of normal laboratory values for studies performed
Use of measuring devices (ruler, string, rod) to assure correct distance from source to detector

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit III: Instrumentation In Vivo

MODULE 2: RECTILINEAR SCANNERS

TASKS

a. Operate rectilinear scanner
b. Select/insert proper collimator for scanner procedures
c. Set proper margins and distance for areas scanned
d. Determine count density required
e. Determine scan speed and line spacing
f. Determine film exposure parameters
g. Process film for viewing
h. Select rate meter scale range and time constant

PERFORMANCE OBJECTIVE

(Stimulus) On receipt of notification from supervisor that patient has arrived at the nuclear medicine laboratory for study

(Behavior) The NMT will prepare the scanning instrument and perform the study requested by the physician

(Conditions) With indirect supervision; using local manuals

(Criteria) A technically adequate study as determined by supervisor; performed in accordance with standard laboratory operating procedures

(Consequence) Maximum information obtained from study for evaluation by physician; minimized radiation exposure to patient

(Next Action) Transmit results of study to physician

KNOWLEDGES AND SKILLS

Knowledge of complete operation of rectilinear scanner, manufacturer's instruction manual
Special handling required for patients who are aged, pediatric, female, infirm, incompetent unconscious, injured
Use of charts, tables, graphs to determine operating parameters consistent with established laboratory procedures
Topographical anatomy
Area limits to set for scanning procedures consistent with portion of anatomy scanned
Principles of collimation and collimation variables

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit III: Instrumentation In Vivo

MODULE 3: STATIONARY IMAGING DEVICES

TASKS

a. Operate gamma-camera basic unit
b. Select/insert proper collimator for stationary imaging studies
c. Determine imaging time/total counts
d. Select parameters for film exposure
e. Operate camera for dynamic/function studies
f. Operate modified gamma camera, e.g., split crystal

PERFORMANCE OBJECTIVE

(Stimulus) On receipt of notification from supervisor that patient is ready for study

(Behavior) The NMT will prepare the gamma-ray camera unit and perform the study prescribed by the physician

(Conditions) With indirect supervision; using local manuals

(Criteria) A technically adequate study as determined by supervisor; performed in accordance with standard laboratory operating procedures

(Consequence) Maximum information obtained from the study for evaluation by physician; minimized radiation exposure to patient

(Next Action) Transmit results of study to physician

KNOWLEDGES AND SKILLS

Knowledge of complete operation of stationary imaging devices; manufacturer's instruction manual

Timing between administration of radionuclide and performance of imaging studies

Special handling required for patients who are aged, pediatric, female, infirm, incompetent, injured, unconscious

Topographical anatomy

Planes, angles, views for various studies performed routinely in the laboratory

Principles of collimation and collimator variables

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT IV: RADIATION SAFETY

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit IV: Radiation Safety

MODULE 1: PRACTICAL RADIATION SAFETY

TASKS

a. Survey/decontaminate areas/equipment
b. Establish boundaries of radiation-controlled areas
c. Inspect facilities for patient with radioactive materials
d. Perform leak test of sealed radioactive sources
e. Prevent spread of contamination following spills or release of radioactive materials
f. Monitor incoming shipments of radionuclides
g. Insure adequacy of shielding in working situation
h. Collect samples from ward/labs for disposal

PERFORMANCE OBJECTIVE

(Stimulus) Routinely or on request of supervisor

(Behavior) The NMT will measure the level of radiation exposure in certain areas and the degree of contamination of sources, work surfaces, and adjacent areas

(Conditions) With indirect supervision; using appropriate survey instruments and methods

(Criteria) Acceptable levels of exposure and/or contamination as indicated in institution's AEC or state license are not exceeded; inspection performed in accordance with local and BuMed manuals, NCRP reports

(Consequence) Determination of need for decontamination, increased shielding, decreased working time or increased source personnel distance

(Next Action) Take any necessary actions to bring levels to acceptable values

KNOWLEDGES AND SKILLS

Calibration, use, limitations of radiation detection systems
Energy and range limitations of radiation survey instruments
Use of manufacturer's operating manuals, NCRP reports, and U.S. government's 10CFR20
Maximum permissible dose
Air and water sampling techniques
Statistics of minimal detectable activities

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit IV: Radiation Safety

MODULE 2: DISPOSAL OF RADIOACTIVE WASTES

TASKS

a. Assay or estimate activity of radioactive materials prior to disposal
b. Select and route radioactive materials for proper disposal
c. Select proper container for radioactive waste

PERFORMANCE OBJECTIVE

(Stimulus) Routinely or on request of supervisor or other radiation worker

(Behavior) The NMT will arrange for and/or give advice on proper methods of disposing of radioactive waste

(Conditions) Without direct supervision

(Criteria) Maximum permissible concentration for radioactive materials released in air and water as indicated in 10CFR20 is not exceeded; disposal performed in accordance with established laboratory operating procedures and federal and BuMed regulations, using appropriate sampling and radiation detection techniques

(Consequence) The burden of radiation imposed on the population from disposal of radioactive wastes is minimized

(Next Action) Record identity, amounts, and conditions of disposal in appropriate log or file

KNOWLEDGES AND SKILLS

Procedures for safe handling of radioactive materials
Theory and operation of instruments for detection, identification, and quantification of radioactive materials
Sources of information on maximum permissible concentration in air and water, e.g., 10CFR20
Methods for estimating activity of nuclides after various periods of decay
Dilution principles
Shielding requirements for radioactive materials

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit IV: Radiation Safety

MODULE 3: RADIATION SAFETY INSTRUMENTATION

TASKS

a. Calibrate area survey instruments
b. Plot calibration curves for survey instruments
c. Verify accuracy of pocket chambers
d. Calibrate personnel dosimetric film

PERFORMANCE OBJECTIVE

(Stimulus) Routinely in accordance with schedule established by laboratory supervisor

(Behavior) The NMT will perform tests to determine precision of equipment and correction factors necessary to maintain accuracy

(Conditions) With indirect supervision; using standardized sources of radioactive materials

(Criteria) Technical review of supervisor; performed in accordance with local standard laboratory practice, NCRP reports

(Consequence) Instrument readings are found to be accurate, reliable, and allow proper assessment of radiation exposure to personnel

(Next Action) Record results of calibration of area survey instruments on the instrument case; record other results in file

KNOWLEDGES AND SKILLS

Radiation detection systems (ion-chamber, Geiger-Müller, scintillation)
Film sensitometry and densitometry
Inverse square law
Interaction of radiation with matter, particularly with respect to scattering
Energy dependence of radiation detection systems
Intensity range limitations of survey instruments
Manufacturers' operating manuals

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit IV: Radiation Safety

MODULE 4: RADIATION SAFETY RECORD KEEPING

TASKS

a. Maintain current files of federal and BuMed radiation control regulations
b. Maintain personnel exposure records
c. Maintain records of radioactive materials received, stored, used and disposed of
d. Maintain records of calibration and leak tests of sealed radiation sources
e. Maintain records of area radiation surveys

PERFORMANCE OBJECTIVE

(Stimulus) Routinely in accordance with established laboratory procedures

(Behavior) The NMT will maintain all files and records

(Conditions) With indirect supervision

(Criteria) Upon review by supervisor files and records are deemed to be current, accurate and complete; kept in an orderly manner such that their contents may be retrieved immediately on demand of regulatory agency inspection officers and in accordance with AEC license for byproduct materials, DHEW regulations and BuMed regulations

(Consequence) A continuous record of personnel radiation exposure and levels of radioactive waste disposed of via air and sewage is maintained for continuous review

KNOWLEDGES AND SKILLS

U.S. government rules and regulations pertaining to use of radioactive materials, i.e., 10CFR20, 30, 35
Operation of gamma-ray spectrometer
Safe handling procedures for radioactive materials
Use of volumetric glassware, syringes
Aseptic technique
Chromatographic techniques
Qualitative analytical techniques (chemistry)
Corrections for radioactive decay
Proper methods for maintenance of quality control tests
Radiometric assay (qualitative and quantitative)
Use of microscope for particle size determination
Turbidity measurement methods
Particle counting methods
Use of millipore filtration systems

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT V: RADIOPHARMACEUTICALS

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit V: Radiopharmaceuticals

MODULE 1: RADIONUCLIDE DISPENSING

TASKS

a. Determine activity concentration and volume required for counting standards
b. Calculate volume of radiopharmaceutical solution for patient
c. Prepare diagnostic/therapy dose
d. Assay diagnostic/therapy dose prior to administration
e. Give oral dose of radiopharmaceutical
f. Administer I.V. dose of radiopharmaceutical

PERFORMANCE OBJECTIVE

(Stimulus) On request of physician or supervisor
(Behavior) The NMT will prepare radiopharmaceutical for administration to patient
(Conditions) With indirect supervision; using volumetric glassware, calibrated syringes, equipment for radionuclide assay
(Criteria) In accordance with prescription, established laboratory procedures and laboratory routine dosage schedule; technical review by supervisor verifies that proper dose, identity, form and activity have been prepared
(Consequence) Patient receives radiopharmaceutical of correct identity, chemical and physical form to within an activity of $\pm$ 10% of prescribed dose
(Next Action) Deliver radiopharmaceutical to physician for administration to patient, or administer dose to patient as determined by standard laboratory practice

KNOWLEDGES AND SKILLS

Safe handling procedures for radioactive materials
Use of volumetric glassware, syringes
Use of charts, graphs, slide rule for determination of radioactive decay
Calculation of volume necessary to provide specified activity
Aseptic technique
Techniques for intravenous infusion
Knowledge of pretreatment or complementary drugs required or contraindicated
Use of calibration equipment (Geiger-Müller, scintillation, ionization chamber) to determine activity experimentally
Proper method of recording administered dose in patient's records, laboratory records

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit V: Radiopharmaceuticals

MODULE 2: RADIONUCLIDE GENERATOR

TASKS a. Elute radionuclide generator

PERFORMANCE OBJECTIVE

(Stimulus)	Routinely and on specific request of supervisor
(Behavior)	The NMT will perform elution procedures to remove a desired daughter-product radiochemical from an ion-exchange column containing a radioactive parent-daughter combination
(Conditions)	With indirect supervision; using eluting solutions, syringes, flasks, vials, commercial generator systems, chart for radioactive decay correction, shielding apparatus
(Criteria)	Technical review by supervisor assures a product that is produced in a sterile manner with minimal probability of introducing pyrogens; according to standard laboratory procedures (manufacturer's instructions); and with verification of the efficiency of elution procedure by radioassay in an ionization chamber calibrator
(Consequence)	A solution of radioactive material is obtained that is sterile, pyrogen free, and of an activity suitable for preparation of a variety of radiopharmaceuticals that may be administered to a patient for diagnostic studies
(Next Action)	Deliver to radiopharmacy technician for radioassay, quality control and labeling procedures

KNOWLEDGES AND SKILLS

Radioactive equilibrium, growth and decay of products
Aseptic technique
Visual inspection of eluting solutions and eluates
Physical and chemical factors affecting release of radiochemicals from ion-exchange resins
Construction and function of components of radionuclide generator

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit V: Radiopharmaceuticals

MODULE 3: RADIOPHARMACEUTICAL QUALITY CONTROL (LOCAL)

TASKS

a. Assay incoming radiopharmaceutical
b. Inspect radiopharmaceutical for clarity
c. Determine identity of radioactive impurities
d. Determine content of radioactive impurities
e. Determine content of chemical impurities
f. Determine bound/unbound radiopharmaceutical
g. Prepare samples for sterility/pyrogen testing
h. Do microscopic particle sizing of radiopharmaceutical
i. Determine specific activity of radiopharmaceutical

PERFORMANCE OBJECTIVE

(Stimulus)	On receipt of radiopharmaceutical from unlicensed source of supply
(Behavior)	The NMT will perform tests to determine the suitability of the radiopharmaceutical for use in humans
(Conditions)	With supervision of a radiopharmacist or chemist; using local operating manuals
(Criteria)	Upon technical review the product is found to satisfy the requirements of U.S.P. and/or the institutional AEC license and DHEW requirements
(Consequence)	A safe, effective radiopharmaceutical is prepared for administration to a patient
(Next Action)	Deliver material to radiopharmacist for storage or immediate use

KNOWLEDGES AND SKILLS

Operation of gamma-ray spectrometer
Safe handling procedures for radioactive materials
Use of volumetric glassware, syringes
Aseptic technique
Chromatographic techniques
Qualitative analytical techniques (chemistry)
Corrections for radioactive decay
Proper methods for maintenance of quality control charts
Radiometric assay (qualitative and quantitative)
Use of microscope for particle size determination
Turbidity measurement methods
Particle counting methods
Use of millipore filtration systems

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit V: Radiopharmaceuticals

MODULE 4: ASSAY OF RADIOACTIVE MATERIALS

TASKS

a. Assay radioactive materials by re-entrant ionization chamber
b. Assay radioactive materials by comparison with known standard
c. Identify gamma-emitting radionuclide by gamma-ray spectrometry

PERFORMANCE OBJECTIVE

(Stimulus) Routinely on receipt of shipment of radioactive material from DHEW-approved supplier and routinely prior to administration of radioactive material to patient

(Behavior) The NMT will perform studies to determine the identity and activity of a radionuclide

(Conditions) With indirect supervision; using radiation analyzer, scintillation counter, ionization chamber, local operating manual

(Criteria) Results are checked by supervisor against manufacturer's assay or previous laboratory assay results

(Consequence) The correct dose may be confidently prepared and given to the patient

(Next Action) Store shipment if acceptable or dilute and prepare dose if necessary and deliver to technologist or physician for administration

KNOWLEDGES AND SKILLS

Theory of operation of complete gamma-ray spectrometer, ionization chamber
Radioisotope decay schemes, gamma-ray spectra
Safe handling procedures for radioactive materials
Use of volumetric glassware, syringes
Aseptic technique
Use of charts, graphs, tables, slide rule for determination of radioactive decay
Proper methods of maintaining inventory control of radioactive materials

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT VI: PREPARATION FOR DIAGNOSTIC STUDIES

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit VI: Preparation for Diagnostic Studies

MODULE 1: PREPARATION OF RADIOPHARMACEUTICALS

TASKS

a. Prepare radioactively labeled sulfur colloid
b. Prepare radioactively labeled albumin microspheres
c. Prepare radioactively labeled DTPA
d. Prepare radioactively labeled diphosphonate
e. Prepare radioactively labeled polyphosphate
f. Prepare radioactively labeled albumin macroaggregates

PERFORMANCE OBJECTIVE

(Stimulus)	Routinely in accordance with current inventory or on receipt of request from supervisor or physician
(Behavior)	The NMT will prepare radiopharmaceuticals from kits by labeling with short-lived radionuclides such as Tc-99m or In-113
(Conditions)	With indirect supervision; using appropriate glassware, bacterial filters, sonicators, syringes, pH meters, water baths, magnetic stirrers
(Criteria)	Prepared in strict accordance with instructions obtained from radiopharmaceutical supplier; animal testing, chromatography and/or local laboratory procedural methods; quality of product determined by microscopic particle size distribution, animal distribution studies to determine size distribution of particles, sterility testing by standard bacterial culture techniques, pyrogen testing by rabbit temperature method
(Consequence)	Preparation of a sterile, pyrogen-free product of proper tonicity, pH, and particle size so that suitable scanning and/or function studies can be performed
(Next Action)	Store in refrigerator or freezer, or deliver to other technician for use in patient's studies

KNOWLEDGES AND SKILLS

Calculation of activity of radionuclide, yield of generators
Techniques of eluting radionuclides from generator
Use of pipettes, burettes, syringes, volumetric glassware

Determination of pH, osmolality
Calculation of concentration and activity of radiopharmaceutical
Stability of solutions, colloids, macro-aggregates
Effects of temperature on size of particles produced
Use of sonicator, heating bath, magnetic stirrers
Use of bacterial filters, millipore, sintered glass
Methods of avoiding radioactive as well as bacterial contamination
Methods of preparing apyrogenic glassware and stoppers
Methods for preserving and storing sterile materials
Methods for safely handling and storing radio-active materials
Use of ionization chamber for calibration of radionuclides
Use of area survey equipment such as Geiger-Müller counter
Aseptic technique

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit VI: Preparation for Diagnostic Studies

MODULE 2: PATIENT ORIENTATION

TASKS

a. Ask patient/check chart for contraindication to treatment/procedure
b. Check request form/interrogate patient to determine pregnancy status
c. Check with patient/chart to determine if patient previously received radionuclides
d. Review with patient printed instructions for examination/therapy procedures
e. Have patient sign consent form where necessary
f. Inform patient of procedures required prior to/ during examination/test
g. Explain procedures to patient
h. Ascertain if patient has been prepared for test/treatment procedure
i. Instruct patient in proper urine/feces specimen collection method

PERFORMANCE OBJECTIVE

(Stimulus) Routinely on arrival of patient at nuclear medicine laboratory

(Behavior) The NMT will interview the patient prior to study, indicating the nature of the study, checking for any contraindications to it, and instructing the patient in proper methods of specimen collection, if necessary

(Conditions) With indirect supervision

(Criteria) In accordance with general guidelines established by physician in charge of laboratory for the specific test designated; tactfully, observing social customs and medical ethics

(Consequence) Patient is properly prepared psychologically for tests to be performed resulting in efficient performance of test; inappropriate testing is avoided

(Next Action) Direct ambulatory patient or arrange for patient transportation to proper room for test or examination to be performed

KNOWLEDGES AND SKILLS

Use of interrogation form and/or laboratory check list of conditions which contraindicate performance of the test or its modification
Procedures for all tests performed in the laboratory and techniques for relating this information to patient in layman's terms
Methods for collecting uncontaminated samples of feces and urine
Medical ethics, confidentiality of privileged information

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit VI: Preparation for Diagnostic Studies

MODULE 3: PATIENT PREPARATION FOR STUDY

TASKS

a. Arrange for female attendant's presence where appropriate
b. Prepare patient for lumbar puncture
c. Prepare patient for thoracentesis
d. Prepare patient for abdominocentesis
e. Prepare patient for arterial puncture

PERFORMANCE OBJECTIVE

(Stimulus) On arrival of patient at examining room/operating room

(Behavior) The NMT will prepare patient for operative procedure, arranging for presence of female attendant from Red Cross, patient's attendant service or staff when necessary, i.e., when a female patient is to be examined

(Conditions) With physician's supervision

(Criteria) Upon technical review by physician it is verified that patient preparation has been accomplished according to established surgical preparative techniques and maintaining patient modesty

(Consequence) Operation is performed in an aseptic field, lessening the chances of subsequent infection at operation site

(Next Action) Notify physician that patient is ready for operation; obtain radioactive material for instillation

KNOWLEDGES AND SKILLS

Aseptic technique
Use of skin cleansing and antiseptic agents
Surgical packs necessary for each operative procedure
Medical ethics, confidentiality of information concerning patient

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT VII: PREPARATION FOR RADIATION THERAPY

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit VII: Preparation for Radiation Therapy

MODULE 1: PREPARATION FOR RADIATION THERAPY

TASKS
a. Prepare therapy dose of radionuclide
b. Prepare apparatus for administration of radionuclide

PERFORMANCE OBJECTIVE

(Stimulus)	On request of supervisor
(Behavior)	The NMT will prepare facilities and equipment for physician to administer therapy dose
(Conditions)	With indirect supervision; using survey meters, dose calibrators, infusion equipment, intravenous solutions
(Criteria)	Upon technical review by supervisor is found adequate; performed in accordance with local standard procedures
(Consequence)	The patient receives the correct dose, with a minimum of radiation exposure to attending personnel
(Next Action)	Notify physician that apparatus is ready for use on patient

KNOWLEDGES AND SKILLS

Radiation safety principles and procedures (time, distance, shielding)
Use of ion chamber and Geiger-Müller survey meters
Sterile technique
Use of scintillation counter and/or ion chamber for radioassay
Possible routes of administration: oral (I-131), IV. (P32), intracavitary (Au-198, Y90, P32)

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit VII: Preparation for Radiation Therapy

MODULE 2: RADIATION THERAPY ASSISTANCE

TASKS a. Assist physician in administration of radionuclides

PERFORMANCE OBJECTIVE

(Stimulus)	On request of supervisor
(Behavior)	The NMT will assist the nuclear physician in administering therapeutic doses of radioactive materials to a patient
(Conditions)	With supervision by the physician who administers the radioactive material
(Criteria)	Approval of physician determines whether job is performed properly; according to standard local procedures
(Consequence)	The patient is administered a dose of radioactive material expeditiously, with minimal radioactive exposure to attending personnel
(Next Action)	Arrange for transfer of patient to room

KNOWLEDGES AND SKILLS

Radioactive safety principles and procedures
Sterile technique
Administration of intravenous and intracavitary solutions

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit VII: Preparation for Radiation Therapy

MODULE 3: RADIATION THERAPY FOLLOW-UP STUDIES

TASKS

a. Perform post-therapy thyroid scan
b. Perform post-therapy whole-body scan
c. Perform post-therapy urinary excretion study
d. Measure/dilute/preserve specimens, e.g., urine, blood, ascitic fluid, for subsequent testing

PERFORMANCE OBJECTIVE

(Stimulus)	On request of supervisor
(Behavior)	The NMT will perform studies on the patient or specimens from the patient to determine the amount of radioactive material remaining in the patient's body
(Conditions)	With indirect supervision; using *in vivo* and *in vitro* counting and scanning instrumentation
(Criteria)	On technical review by supervisor, studies are determined to be accurate; performed according to local standard procedures
(Consequence)	The residual burden of radioactive material in the patient is accurately determined, leading to better estimates of the radiation hazard associated with the patient, and patient's stay in the hospital is minimized
(Next Action)	Report and record results of study

KNOWLEDGES AND SKILLS

Radiation safety principles and procedure
Use of gamma-ray detection and counting apparatus
Assay methodology for high activity sources
Gamma-ray shielding principles
Maximum permissible radiation dose for personnel and general public (see U.S. government publication 10CFR20)

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT VIII: THYROID FUNCTION STUDIES IN VIVO

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit VIII: Thyroid Function Studies In Vivo

MODULE 1: I-131 THYROID SCAN (RECTILINEAR SCANNER)

TASKS

a. Perform I-131 thyroid scan
b. Set up scintillation scanner for thyroid scan with I-131
c. Process film obtained in scanning procedure
d. File results of scan

PERFORMANCE OBJECTIVE

(Stimulus)	On request of supervisor
(Behavior)	The NMT will scan the area of the patient's thyroid gland to secure an image that is representative of the distribution of I-131 in the gland and adjacent areas, process the film obtained and file satisfactory scans
(Conditions)	With indirect supervision; using scintillation scanner and manufacturer's operating manual
(Criteria)	Results are deemed satisfactory upon technical review of nuclear physician; performed according to established laboratory procedures
(Consequence)	An accurate determination of the regional distribution of I-131 in the gland and adjacent areas is obtained, leading to an estimate of gland size shape, extension, and the functional status of any thyroid nodules present
(Next Action)	Repeat procedure if first study was inadequate or if repeat scans with modifications are requested by nuclear physician

KNOWLEDGES AND SKILLS

Complete theory and operation of scintillation scanning instrument
Theory and use of multihole collimators
Statistics of area scanning
Mathematics necessary for determination of scan speed, line spacing, given a particular count rate and area to scan
Film processing procedures and techniques
Thyroid physiology and anatomy

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit VIII: Thyroid Function Studies In Vivo

MODULE 2: I-131 THYROID UPTAKE MEASUREMENT

TASKS a. Perform I-131 thyroid uptake measurement

PERFORMANCE OBJECTIVE

(Stimulus)	Upon receipt of request from supervisor
(Behavior)	The NMT will make measurements on patient and standard sources in order to determine the fraction of administered I-131 activity concentrated in the thyroid gland
(Conditions)	With indirect supervision; using NaI scintillation counter detector probe, distance measuring instrument
(Criteria)	Performed according to established laboratory procedure; results should be within the range of established laboratory values for the states of eu-, hypo-, or hyperthyroidism; results are deemed satisfactory on review by supervisor
(Consequence)	An accurate assessment of the I-131 contained in the thyroid gland, leading to an estimate of the patient's thyroid gland function
(Next Action)	Record results in appropriate chart and schedule patient for further tests of thyroid function, e.g., TSH stimulation, perchlorate washout, Cytomel suppression, as determined by the nuclear physician

KNOWLEDGES AND SKILLS

Use and complete operation of scintillation probe detectors
Thyroid function
Superficial anatomy of the thyroid gland and neck
Statistics of low-level radioactivity counting
Methods of calculating percent administered activity in the thyroid gland

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit VIII: Thyroid Function Studies In Vivo

MODULE 3: TSH STIMULATION TEST

TASKS a. Perform TSH stimulation test

PERFORMANCE OBJECTIVE

(Stimulus)	On request of supervisor
(Behavior)	The NMT will make background measurements on the patient and measure the patient's thyroid gland I-131 activity at 2 and 24 hours following administration of I-131
(Conditions)	Measurements are made with indirect supervision (see I-131 thyroid uptake measurement); the dose of thyroid stimulating hormone (TSH) may be given by the NMT with direct supervision by the nuclear physician
(Criteria)	Results are judged acceptable on technical review by the nuclear physician
(Consequence)	An assessment of the cause of hypothyroidism is obtained
(Next Action)	Report results to physician; record in chart

KNOWLEDGES AND SKILLS

Effects of thyroid stimulating hormone
Techniques of intramuscular injection (for giving TSH)

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit VIII: Thyroid Function Studies In Vivo

MODULE 4: PERCHLORATE WASHOUT TEST

TASKS a. Perform perchlorate washout test

PERFORMANCE OBJECTIVE

(Stimulus)	On request of supervisor
(Behavior)	The NMT will perform thyroid uptake measurements prior to and following administration of an oral dose of $KClO_4$ to the patient
(Conditions)	The uptake measurements will be performed with indirect supervision; the dose of $KClO_4$ may be given by the NMT with direct supervision by the nuclear physician
(Criteria)	Performed according to local standard procedures, and upon technical review by the nuclear physician, results are deemed satisfactory
(Consequence)	An estimate of the ability of the patient's thyroid gland to organify and bind administered iodide is obtained, leading to correct diagnosis
(Next Action)	Report results to nuclear physician; record in chart

KNOWLEDGES AND SKILLS

Correct dosage of $KClO_4$ and its effects on the thyroid uptake of I-131
Use and complete operation of scintillation probe detectors
Thyroid function
Superficial anatomy of the thyroid gland and neck
Statistics of low-level radiation counting
Methods of calculating percent administered activity in the thyroid gland

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit VIII: Thyroid Function Studies In Vivo

MODULE 5: CYTOMEL SUPPRESSION TEST

TASKS a. Perform Cytomel suppression test

PERFORMANCE OBJECTIVE

(Stimulus)	Upon receipt of request from supervisor
(Behavior)	The NMT will perform thyroid uptake study after patient has received a dose of Cytomel (T_3)
(Conditions)	The uptake study will be performed with indirect supervision (see I-131 thyroid uptake study); the dose of TSH may be given by the NMT with direct supervision by the nuclear physician
(Criteria)	Upon technical review by the nuclear physician, results are deemed satisfactory
(Consequence)	An estimate of the functional status of the patient's thyroid gland is obtained, leading to correct diagnosis
(Next Action)	Report results to nuclear physician; record in chart

KNOWLEDGES AND SKILLS

Correct dose of Cytomel to administer and its effect on thyroid uptake studies

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit VIII: Thyroid Function Studies In Vivo

MODULE 6: THYROID IMAGING (GAMMA-RAY CAMERA)

TASKS

a. Set up gamma-ray camera for thyroid imaging with I-131 or Tc-99m
b. Select and change collimators
c. Perform Tc-99m or I-131 thyroid imaging with gamma-ray camera
d. Process film
e. File results of study

PERFORMANCE OBJECTIVE

(Stimulus)	On request of supervisor
(Behavior)	The NMT will obtain an image that is representative of the distribution of I-131 or Tc-99m in the thyroid gland and adjacent areas of the neck, process the film and file satisfactory film images
(Conditions)	With indirect supervision; using gamma-ray camera and manufacturer's operating manual
(Criteria)	Performed according to established laboratory procedures; results deemed satisfactory on technical review by the nuclear physician
(Consequence)	An accurate determination of the regional distribution of I-131 or Tc-99m in the thyroid gland and adjacent areas is obtained, leading to an estimate of gland size, shape, extension and functional status of any thyroid nodules present
(Next Action)	Repeat procedure if first study was inadequate or if repeat images or different views are requested by the nuclear physician

KNOWLEDGES AND SKILLS

Theory and operation of gamma-ray scintillation camera
Theory, selection and replacement of collimators
Thyroid physiology and metabolism of iodide and pertechnetate ion
Use of 35 mm, 70 mm or polaroid camera, according to the particular gamma-ray camera
Operation of cathode ray oscilloscope
Statistics of imaging

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT IX: THYROID FUNCTION STUDIES IN VITRO

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit IX: Thyroid Function Studies In Vitro

MODULE 1: THYROID-BINDING GLOBULIN LEVEL IN SERUM

TASKS a. Determine thyroid-binding globulin (TBG) level in serum

PERFORMANCE OBJECTIVE

(Stimulus)	On receipt of specimen and request for specific test related to thyroid function
(Behavior)	The NMT will test to determine the level of thyroid-binding globulin in the patient's serum
(Conditions)	With indirect supervision; using appropriate controls, standards, reagents, volumetric glassware
(Criteria)	Upon technical review by supervisor, test is deemed to have been satisfactorily performed; in accordance with standard laboratory routine and U.S. Navy manuals (chemistry and/or radioisotope technique)
(Consequence)	A quantitative analysis of the serum level of circulating TBG
(Next Action)	Record and report results

KNOWLEDGES AND SKILLS

Principles and techniques for determining TBG level in serum
Interpretation of thyroid function test results, normal ranges
Extraneous factors which may influence testing procedures for TBG
Quantitative analytical chemistry techniques

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit IX: Thyroid Function Studies In Vitro

MODULE 2: TRI-IODOTHYRONINE (T_3) LEVEL IN SERUM

TASKS a. Do T_3 (tri-iodothyronine) testing

PERFORMANCE OBJECTIVE

(Stimulus) Upon receipt of specimen and request for determination of T_3 level in serum

(Behavior) The NMT will test to determine the level of tri-iodothyronine in the patient's serum

(Conditions) With indirect supervision; using commercially available kits, resin columns, radioactively labeled T_3, well-type scintillation counters

(Criteria) Upon technical review of supervisor, the test is deemed to have been satisfactorily performed; in accordance with established laboratory procedures and U.S. Navy manuals

(Consequence) A semiquantitative analysis of T_3 levels is obtained and compared to standard serum controls, providing information for an evaluation of the patient's thyroid gland function

(Next Action) Record and report results

KNOWLEDGES AND SKILLS

Principles and techniques of testing for tri-iodothyronine level in serum
Normal range of test results
Extraneous factors which may influence test
Use of volumetric glassware
Statistical limits of reliability of radioactivity counting
Techniques for storage, use and handling radioactive materials

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit IX: Thyroid Function Studies In Vitro

MODULE 3: TETRAIODOTHYRONINE (T_4) LEVEL IN SERUM

TASKS a. Do T_4 (tetraiodothyronine) testing

PERFORMANCE OBJECTIVE

(Stimulus)	Upon receipt of specimen and request for determination of T_4 level
(Behavior)	The NMT will perform tests, including the Murphy-Pattee, ion-exchange column and immunoassay tests, to determine the level of circulating thyroid hormone in the patient's serum
(Conditions)	With indirect supervision; using commercially available kits in accordance with manufacturer's instructions, resin columns, radioactively labeled T_4, well-type scintillation counters, stop watch, water bath, control serum, standard curves
(Criteria)	Upon technical review of supervisor, test(s) is(are) verified to have been satisfactorily performed; in accordance with established laboratory procedures (Navy manuals)
(Consequence)	A semiquantitative analysis of the level of patient's circulating thyroid hormone is determined, leading to correct estimate of status of patient's thyroid function
(Next Action)	Record and report results

KNOWLEDGES AND SKILLS

Normal range of test results
Extraneous factors that influence test
Use of volumetric glassware
Techniques for storage, use and handling of radioactive materials
Use of well-type scintillation counter
Technique of plotting standard curves on rectilinear graph paper
Principles and techniques of T_4 testing, e.g., Murphy-Pattee, ion-exchange column, immunoassay procedures

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT X: HEMATOLOGY

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit X: Hematology

MODULE 1: RED CELL, PLASMA AND BLOOD VOLUME

TASKS
a. Determine red cell volume
b. Determine plasma volume
c. Determine total blood volume (dual tracer)

PERFORMANCE OBJECTIVE

(Stimulus) Upon notification from supervisor that a blood volume, plasma, and/or red cell volume is needed on a particular patient

(Behavior) The NMT will perform all steps that are delegated to him by the nuclear physician to determine the patient's plasma, red cell and/or blood volume

(Conditions) With indirect supervision; using U.S. Navy manuals, IHSA, Cr-51, Tc-99m as appropriate, pipettes, syringes, well-type scintillation counter

(Criteria) Technical review by supervisor establishes that aseptic technique has been maintained, standard laboratory procedures have been followed and results are consistent with the patient's condition

(Consequence) An accurate assessment is obtained of the volume of blood, red cells and/or plasma circulating in the patient's vascular system

(Next Action) Record and report results

KNOWLEDGES AND SKILLS

Aseptic technique
Dilution methods
Venipuncture
Anticoagulants for parenteral use
Techniques for collection, storage and labeling of blood and red cells
Operation and use of well-type scintillation counter and single-channel analyzer
Hematocrit determination
Calculation of blood, plasma, red cell volume from sample and standard count rate
Use of centrifuge
Corrections for radioactive decay
Statistics of counting

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit X: Hematology

MODULE 2: RED CELL SURVIVAL TIME

TASKS a. Determine red cell survival time

PERFORMANCE OBJECTIVE

(Stimulus) Upon notification from supervisor that a red cell survival study is needed on a particular patient

(Behavior) The NMT will perform all steps that are delegated to him by the nuclear physician to determine the survival time of the patient's red blood cells

(Conditions) With indirect supervision; using Cr-51, pipettes, syringes, well-type scintillation counter

(Criteria) Technical review by supervisor establishes that aseptic technique has been maintained, standard laboratory procedures (U.S. Navy manuals) have been followed and results are consistent with the patient's condition

(Consequence) An accurate assessment is obtained of the survival time of a randomly labeled group of circulating red blood cells (Cr-51 label) or a cohort of labeled red blood cells [P-32 labeled di-isopropyl fluoro-phosphate (DFP-32) method]

(Next Action) Record and report results

KNOWLEDGES AND SKILLS

Aseptic technique
Dilution methods
Venipuncture
Anticoagulants for parenteral use
Techniques for collection, storage and labeling of blood and red cells (Cr-51 for random label, DFP-32 for cohort label)
Operation and use of well-type scintillation counter and single-channel analyzer (Cr-51 method)
Operation and use of beta-particle counting system (DFP-32 method)
Hematocrit determination
Calculation of blood/plasma/red cell volume from sample and standard count rate
Use of centrifuge
Corrections for radioactive decay
Statistics of counting
Techniques to plot data on graph paper
Proper storage of samples for subsequent counting

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit X: Hematology

MODULE 3: PLATELET SURVIVAL TIME

TASKS a. Determine platelet survival time

PERFORMANCE OBJECTIVE

(Stimulus)	Upon notification from supervisor that a platelet survival study is needed on a particular patient
(Behavior)	The NMT will perform all steps that are delegated to him by the nuclear physician to determine the survival time of the patient's platelets
(Conditions)	With indirect supervision; using Cr-51, pipettes, syringes, well-type scintillation counter
(Criteria)	Technical review by supervisor establishes that aseptic technique has been maintained, standard laboratory procedures (U.S. Navy manuals) have been followed and results are consistent with the patient's condition
(Consequence)	An accurate assessment is obtained of the survival time of platelets circulating in the patient's vascular system
(Next Action)	Record and report results

KNOWLEDGES AND SKILLS

Aseptic technique
Dilution methods
Venipuncture techniques
Anticoagulants for parenteral use
Techniques for collection, separation, storage and labeling of platelets
Operation and use of well-type scintillation counter and single-channel analyzer
Hematocrit determination
Use of centrifuge
Corrections for radioactive decay
Statistics of counting
Procedures to plot data on graph paper
Proper storage of samples for subsequent counting

Competancy: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit X: Hematology

MODULE 4: SPLENIC SEQUESTRATION OF ERYTHROCYTES

TASKS a. Determine splenic sequestration of erythrocytes

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request of supervisor
(Behavior)	The NMT will perform all steps that are delegated to him by the nuclear physician to determine the ratio of red cells in the spleen to those in other parts of the circulatory system
(Conditions)	With indirect supervision; using labeled red blood cells, Cr-51, syringes, pipettes, scintillation counter probe, and anticoagulants
(Criteria)	Technical review by supervisor establishes that aseptic technique has been maintained, standard laboratory procedures (U.S. Navy manuals) have been followed and results are consistent with the patient's condition
(Consequence)	Determination of ratio of labeled red blood cell activity in spleen to liver and precordium, providing data for assessment of status of reticuloendothelial system
(Next Action)	Record and report results

KNOWLEDGES AND SKILLS

Aseptic techniques
Methods for labeling red blood cells
Anticoagulants
Venipuncture techniques
Techniques for collection, storage and labeling of red blood cells
Operation and use of scintillation probe detector, single-channel analyzers
Choice and replacement of collimators
Superficial anatomy and probe positioning
Statistics of counting
Calculations of activity ratios for organ combinations

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit X: Hematology

MODULE 5: BLOOD LOSS STUDIES

TASKS a. Perform gastrointestinal blood loss studies

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request of the supervisor
(Behavior)	The NMT will perform tests to determine the fraction of the patient's radioactively labeled blood which appears in the stool at various times after intravenous administration of labeled red blood cells (NMT removes blood from patient, labels the red blood cells with Cr-51 or Tc-99m and reinjects labeled blood into patient)
(Conditions)	With indirect supervision; using radioactive materials (Cr-51 or Tc-99m), well-type scintillation counter, syringes, pipette, anticoagulant
(Criteria)	Technical review by the supervisor establishes that the study has been performed in a technically satisfactory manner, maintaining sterile technique and leading to useful results
(Consequence)	An estimate of the amount of blood lost from the patient's vascular system into the gastrointestinal tract is obtained, leading to a diagnosis for the patient's anemia
(Next Action)	Report and record results

KNOWLEDGES AND SKILLS

Complete technique for blood volume determination using either Cr-51 or Tc-99m labeled cells
Collection methods for feces to prevent urine contamination
Use of well-type and probe-type scintillation counters (gamma)
Calculation of percent of circulating Cr-51 or Tc-99m which appears in stool (feces) samples collected from patient
Safe handling of radioactive materials

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit X: Hematology

MODULE 6: B_{12} ABSORPTION STUDIES

TASKS a. Determine vitamin B_{12} absorption

PERFORMANCE OBJECTIVE

(Stimulus) Upon request of supervisor

(Behavior) The NMT will perform tests to determine the amount of an orally administered dose of radioactively labeled cyanocobalamin (vitamin B_{12}) which is absorbed from the gastrointestinal tract, with or without a supplementary dose of intrinsic factor

(Conditions) With indirect supervision; possibly using two isotopes of cobalt simultaneously from among Co57, Co58 or Co60, well-type scintillation counter and syringes

(Criteria) Technical review by the supervisor establishes that the test(s) have been performed in a technically satisfactory manner, according to local laboratory procedures (U.S. Navy manual), and that the results are consistent with the patient's condition or provisional diagnosis

(Consequence) An estimate is obtained of the amount of orally-administered radioactively-labeled vitamin B_{12} which is absorbed by the patient, with or without supplemental intrinsic factor; estimate provides data for possible confirmation of a diagnosis of pernicious anemia

(Next Action) Report and record results

KNOWLEDGES AND SKILLS

Mechanism of absorption and excretion of vitamin B_{12}

Effects of exogenous intramuscular B_{12} on excretion rate of vitamin B_{12}

Techniques for collection, storage and handling of urine, feces and plasma according to the particular form of the test used

Use of probe-type and well-type gamma scintillation counter

Aseptic technique

Simultaneous counting technique for tests using two cobalt radioisotopes

Calculation of percent of administered dose recovered in urine, feces or plasma, depending on the particular form of the test used

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT XI: DIGESTIVE TRACT STUDIES

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XI: Digestive Tract Studies

MODULE 1: PAROTID SCAN

TASKS a. Perform parotid scan

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request of supervisor
(Behavior)	The NMT will perform imaging procedures sufficient to outline the location, size, shape and relative function of the parotid glands
(Conditions)	With indirect supervision; according to local standard procedure (U.S. Navy manual); using rectilinear scanner or gamma-ray camera, Tc-99m, polaroid film or standard x-ray type film
(Criteria)	Review of film images by supervisor verifies that images are technically adequate for providing information for diagnostic evaluation
(Consequence)	A two dimensional image of the distribution of Tc-99m (as pertechnetate) throughout the region of the neck and lower jaw is obtained and provides data for possible diagnosis of disease or abnormal condition of the salivary glands
(Next Action)	File films for conference; file reports after they are dictated by nuclear physician

KNOWLEDGES AND SKILLS

Use of gamma-ray camera and rectilinear scanner
Selection of collimators and operating parameters
Administration of radiopharmaceuticals intravenously with direct supervision of nuclear physician
Gross anatomy of lower jaw and neck
Safe handling techniques for use of radioactive materials
Statistics of imaging
Film processing

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XI: Digestive Tract Studies

MODULE 2: INTESTINAL FAT ABSORPTION

TASKS a. Determine intestinal fat absorption

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request from supervisor
(Behavior)	The NMT will perform studies to determine the fraction of orally administered neutral fats and fatty acids which is absorbed from the patient's gastrointestinal tract
(Conditions)	With indirect supervision; using I-131 labeled triolein and oleic acid, charcoal markers, well- or probe-type scintillation counter, standard lab procedures (U.S. Navy manual)
(Criteria)	Review of results by supervisor establishes that the tests are technically correct and of sufficient quality to provide useful information for diagnostic evaluation
(Consequence)	Results of the test help determine whether a patient is able to split neutral fats into fatty acids, providing data for the physician to make a differential diagnosis of pancreatic lipase insufficiency or malabsorption syndrome
(Next Action)	Record and report results

KNOWLEDGES AND SKILLS

Safe handling, storage and use of radioactive materials
Estimates of activity of radiopharmaceutical
Preparation of emulsions for administration of labeled fats
Methods for collecting feces uncontaminated with urine
Homogenization of feces specimens
Venipuncture techniques
Use of centrifuge
Calculation of percent of administered dose per liter of plasma
Calculation of percent of dose found in stools up until time that charcoal marker appears
Statistics of low-level counting

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XI: Digestive Tract Studies

MODULE 3: PANCREAS SCAN

TASKS a. Perform pancreas scan

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request of supervisor
(Behavior)	The NMT will perform imaging studies sufficient to outline the distribution of radioactively labeled selenomethionine as a function of time after intravenous administration of this agent
(Conditions)	With indirect supervision; using standard laboratory procedures (U.S. Navy manual), rectilinear scanner or gamma-ray camera, Se-75 selenomethionine
(Criteria)	Review of images by the supervisor assures results that are technically satisfactory to provide useful information for diagnostic evaluation
(Consequence)	A series of images is obtained of the pancreatic distribution and time-course of selenomethionine as it is transported to the pancreas, moves through and is finally excreted, leading to a correct diagnosis in the case of suspected pancreatic disease
(Next Action)	File films for conference; file reports after dictation by nuclear physician

KNOWLEDGES AND SKILLS

Use of gamma-ray camera and rectilinear scanner
Selection of collimator and instrument operating parameters
Administration of radiopharmaceutical intravenously, with direct supervision of nuclear physician
Anatomy of pancreas and upper left abdominal quadrant
Topographical landmarks of abdomen
Safe handling techniques for use of radioactive materials
Statistics of imaging
Film processing

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XI: Digestive Tract Studies

MODULE 4: LIVER FUNCTION STUDY

TASKS a. Perform rose bengal dynamic liver function study

PERFORMANCE OBJECTIVE

(Stimulus) Upon request of supervisor
(Behavior) The NMT will perform studies sufficient to determine the time course of uptake of radioactively labeled rose bengal in the patient's liver
(Conditions) With indirect supervision; according to local standard operating procedures (U.S. Navy manual), using probe-type gamma scintillation counter, radioactive rose bengal
(Criteria) Review of results by the supervisor assures results that are technically satisfactory to provide useful information for diagnostic evaluation
(Consequence) The results of this study allow an estimate to be made of the relative function of the polygonal cells of the liver
(Next Action) Perform routine liver scan for determination of distribution of polygonal cell activity

KNOWLEDGES AND SKILLS

Use of probe-type gamma scintillation detector and single-channel analyzer
Selection of collimator and instrument operating parameters
Administration of radiopharmaceutical intravenously, with direct supervision of nuclear physician
Anatomy and function of liver
Topographic landmarks of abdomen
Safe handling techniques for use of radioactive materials
Low-level counting statistics
Calculation of dose of radiopharmaceutical necessary
Procedure for plotting data points on linear graph paper

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT XII: RENAL FUNCTION STUDIES

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XII: Renal Function Studies

MODULE 1: RENAL BLOOD FLOW STUDY

TASKS
a. Perform radionuclide renal function study
b. Perform renal blood flow study

PERFORMANCE OBJECTIVE

(Stimulus) Upon request of supervisor

(Behavior) The NMT will perform studies to indicate the time course of renal uptake and release of radioactively labeled substances which are filtered via the glomeruli

(Conditions) With indirect supervision; according to local standard procedure (U.S. Navy manual); using dual-probe scintillation system, or split crystal gamma-ray camera, strip chart recorders, radioactively labeled (I-131) Hippuran or Hypaque, or Hg197 labeled chlormerodrin

(Criteria) Review of activity/time curves by the nuclear physician assures results that are technically satisfactory to provide useful information for diagnostic evaluation

(Consequence) A pair of activity-time curves is obtained which reveals the relative blood flow and function of each kidney, aiding in diagnosis of diseases related to kidney function

(Next Action) Report and record results

KNOWLEDGES AND SKILLS

Use and operating parameters of twin-probe renogram system
Use and operation of split crystal gamma-ray system
Use and operating parameters of dual-strip chart recorder system
Safe handling of radioactive materials
Estimation of activity administered to patient
I.V. administration of radionuclide with direct supervision of nuclear physician

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XII: Renal Function Studies

MODULE 2: GLOMERULAR FILTRATION RATE

TASKS a. Perform study to determine glomerular filtration rate

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request of supervisor
(Behavior)	The NMT will perform studies to determine the rate at which a substance is filtered from the patient's plasma as it passes through the glomeruli of the kidney
(Conditions)	With indirect supervision; according to local standard laboratory procedures (U.S. Navy manual); using syringes, test tubes, well-type scintillation counter, various radiopharmaceuticals, I-131 labeled Hippuran
(Criteria)	Technical review of results by supervisor establishes that a satisfactory study has been performed of a quality sufficient for aiding in diagnosis
(Consequence)	Results of this study allow the nuclear physician to determine the overall functional status of both kidneys, aiding in diagnosis of renal disease
(Next Action)	Report and record results

KNOWLEDGES AND SKILLS

Use of well-type scintillation counter
Volumetric technique with syringes and pipettes
Use of centrifuge
Hematocrit determination
Statistics of radioactivity counting
Safe handling procedures for radioactive materials
Various radiopharmaceuticals which may be used for glomular filtration rate studies
Venipuncture and blood withdrawal techniques
Sampling times

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XII: Renal Function Studies

MODULE 3: KIDNEY SCAN

TASKS a. Perform kidney scan

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request of supervisor
(Behavior)	The NMT will perform imaging studies on a patient to determine the two-dimensional distribution of radiopharmaceutical throughout the kidneys
(Conditions)	With indirect supervision; according to standard local laboratory procedures (U.S. Navy manual); using either rectilinear scanner or gamma-ray camera, various radiopharmaceuticals, including I-131 Hippuran, Hg-197 chlormerodrin
(Criteria)	Technical review of the images by the supervisor verifies that results are technically satisfactory, providing information of diagnostic quality
(Consequence)	An image is obtained on film which is representative of the function and anatomy of the kidneys, allowing the nuclear physician to make a diagnosis concerning the status of the patient's kidneys
(Next Action)	File images for use at conference; record and report results

KNOWLEDGES AND SKILLS

Use and operating parameters for rectilinear scanner
Use and operating parameters for gamma-ray camera
Various radiopharmaceuticals which may be used for renal scanning
The collimator and instrument operating parameters which must be used with each radiopharmaceutical
Safe handling of radioactive materials
Film processing procedures
Optimum time, post-dose, for scanning
Estimation of activity to be administered to patient with direct supervision by physician

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT XIII: CARDIOVASCULAR SYSTEM STUDIES

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XIII: Cardiovascular System Studies

MODULE 1: ANGIOCARDIOGRAPHY

TASKS a. Assist physician in angiocardiography

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request of supervisor
(Behavior)	The NMT will assist the nuclear physician in performing imaging studies of the heart and blood vessels to determine the anatomy and degree of function of the heart and blood vessels (bolus or rapid injection of radiopharmaceutical is done by nuclear physician or cardiologist, with assistance of technician who operates imaging instrumentation)
(Conditions)	With direct supervision; according to local standard operating procedures (U.S. Navy manual); using gamma-ray camera, polaroid film, high speed camera, or magnetic tape storage system, and appropriate radiopharmaceutical (Tc-99m as pertechnetate, I-131 HSA, or Kr-85 gas in solution)
(Criteria)	Review by the nuclear physician determines whether tha studies are of quality sufficient to provide useful information or whether other views or repeat studies at different time intervals are needed
(Consequence)	An indication is obtained of the time course and route of radioactive material through the venae cava, heart chambers, pulmonary artery and aortic arch, providing information for a possible diagnosis of congenital and/or acquired heart disease
(Next Action)	File images for study at conference; file report when completed by nuclear physician; perform static heart blood pool scan

KNOWLEDGES AND SKILLS

Safe use and handling procedures for radioactive materials
Use of gamma-ray camera, collimator
Use of high speed camera system
Use of polaroid camera system
Use of tape storage system for recording and retrieval of information
Use of gas collection and disposal system
Rapid imaging techniques

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XIII: Cardiovascular System Studies

MODULE 2: BLOOD POOL SCAN

TASKS a. Perform blood pool scan

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request of supervisor
(Behavior)	The NMT will perform imaging studies to indicate the distribution of a radiopharmaceutical throughout the blood pool within the chambers of the heart, the placenta, or other organ or structure
(Conditions)	With indirect supervision; using standard local operating procedure (U.S. Navy manual), rectilinear scanner or gamma-ray camera, various radionuclides including Tc-99m labeled RBCs, Cr-51 labeled RBCs or HSA, I-131 labeled HSA
(Criteria)	Review by supervisor verifies that images are of diagnostic quality and provide useful information for diagnostic evaluation
(Consequence)	An estimate is obtained of the magnitude, extension or volume of blood contained within an organ or system
(Next Action)	File images for conference; file reports after nuclear physician has finished evaluation

KNOWLEDGES AND SKILLS

Use of gamma-ray camera and collimators
Administration of radiopharmaceuticals intravenously with direct supervision by nuclear physician
Gross anatomy of patient including pregnant patients
Statistics of imaging

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT XIV: PULMONARY STUDIES

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XIV: Pulmonary Studies

MODULE 1: PERFUSION LUNG SCAN

TASKS a. Perform perfusion lung scan

PERFORMANCE OBJECTIVE

(Stimulus) Upon request of supervisor, after administration of a specific radiopharmaceutical prescribed by the nuclear physician, e.g., Tc-99m labeled microspheres, or macroaggregates; I-131 labeled macroaggregates

(Behavior) The NMT will perform imaging studies, including anterior, posterior, right and left lateral views, of the lungs of a patient who has previously received an intravenous radiopharmaceutical which distributes throughout the lungs in accordance with their blood supply

(Conditions) With indirect supervision; using local standard laboratory procedures (U.S. Navy manual), gamma-ray camera or scanner (single or dual)

(Criteria) Technical review by the supervisor verifies that images obtained provide useful information for diagnostic evaluation

(Consequence) A series of images of the lungs is obtained which aids the nuclear physician in diagnosing pulmonary embolism, lung metastases and other diseases of the lung which are manifested in altering blood flow to the lungs

(Next Action) File images for review conference; record and report results after diagnostic evaluation is complete

KNOWLEDGES AND SKILLS

Use and operating parameters (including selection and replacement of collimators) of gamma-ray camera, single and dual rectilinear scanner

Knowledge of all radiopharmaceuticals which are used in the laboratory for perfusion lung scans, the collimator, instruments and operating parameters for each and the time following administration of radiopharmaceutical in which the study must be completed

Safe handling procedures for radioactive materials

Film processing

Intravenous administration of radiopharmaceuticals with direct supervision by the nuclear physician

Anatomy of the lungs and chest

Recognition of shock and administration of first aid to patient in shock

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XIV: Pulmonary Studies

MODULE 2: INHALATION LUNG SCAN

TASKS a. Perform inhalation lung scan

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request of supervisor
(Behavior)	The NMT will perform studies (repeating views at various times during the desaturation phase) sufficient to indicate the areas of the lung that are ventilated normally and abnormally
(Conditions)	With indirect supervision; using radioactive Xe-133 gas, gamma-ray camera, gas handling apparatus, tank, vial, gas collection bag, closed exhaust system, U.S. Navy manual
(Criteria)	On technical review the supervisor determines that the study is technically adequate, providing an image of diagnostic quality
(Consequence)	A two dimensional image of the patient's lungs is obtained, providing data for assessing the cause of lung disease and diagnosing emphysema and chronic obstructive pulmonary disease
(Next Action)	File film for conference; report and record results after diagnostic evaluation is complete

KNOWLEDGES AND SKILLS

Complete use of gamma-ray camera, including collimator choice and replacement
Film processing
Use of 35 mm or 70 mm camera
Use and safe handling of radioactive gas
Anatomy and physiology of lungs
Xe-133 as it relates to lung ventilation, saturation, and desaturation
Radiation safety, safe methods for disposal of radioactive gas

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT XV: SKELETAL SYSTEM STUDY

This unit includes tha following module:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XV: Skeletal System Study

MODULE 1: BONE SCAN

TASKS a. Perform bone scan

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request from supervisor
(Behavior)	The NMT will perform scanning procedure on a patient to determine the relative distribution of previously administered radiopharmaceuticals which concentrate to a greater or lesser degree in bone and/or bone marrow
(Conditions)	With indirect supervision; using gamma scintillation scanner or stationary imaging device as appropriate at time intervals following administration which are determined by the radiopharmaceutical used: NaF-18, Sr-85Cl, Tc-99m as diphosphonate, pypophosphate, polyphosphate
(Criteria)	Review by supervisor verifies that image is technically satisfactory with sufficient anatomic detail and photographic density and that it provides useful clinical information
(Consequence)	A two-dimensional image is obtained which allows the nuclear physician to estimate the relative function and anatomical configuration of various parts of the skeletal and bone marrow systems
(Next Action)	File film for appropriate clinical conference or for nuclear physician's assessment and report

KNOWLEDGES AND SKILLS

Theory and use of gamma-ray scintillation scanning system (rectilinear scanner), gamma-ray camera imaging system
Proper collimators and techniques for various bone scanning agents in common use, e.g., F-18, Sr-85, Tc-99m
Skeletal and bone marrow anatomy
Film processing techniques

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT XVI: CENTRAL NERVOUS SYSTEM STUDIES

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XVI: Central Nervous System Studies

MODULE 1: CEREBRAL BLOOD FLOW STUDIES

TASKS

a. Perform cerebral blood flow studies

PERFORMANCE OBJECTIVE

(Stimulus) Upon request of supervisor, after bolus injection of radiopharmaceutical is administered by physician

(Behavior) The NMT will perform serial brain imaging procedures on a patient to determine the relative rate of blood flow to each side of the brain

(Conditions) With direct supervision; according to local standard operating procedures (U.S. Navy manual); using gamma-ray camera, polaroid film or high speed conventional 35- or 70-mm film, Tc-99m as pertechnetate, Yb-169, In-111

(Criteria) Upon technical review by supervisor results are found to provide useful information for diagnostic evaluation

(Consequence) An indication is obtained of the relative time of first appearance, peak activity and disappearance of radiopharmaceutical from the brain, providing information of value in diagnosis of vascular lesions of the brain

(Next Action) Perform routine brain scan following this, then report and record results

KNOWLEDGES AND SKILLS

Theory and use of gamma-ray camera system
Proper collimators and techniques for various brain scanning agents, e.g., Tc-99m, Yb-169, In-111
Topographic anatomy of brain and skull
Dosage of complementary drugs which may sometimes be administered by NMT with direct supervision by the nuclear physician, e.g., $KClO_4$, atropine
Film processing techniques
Methods of restraining patient
Handling of unconscious/incompetent/pediatric patient
Proper views for cerebral blood flow study
Rapid imaging technique

Competency: NUCLEAR MEDICINE TECHNICAIN (NMT)

Unit XVI: Central Nervous System Studies

MODULE 2: BRAIN IMAGING

TASKS a. Perform routine brain scan

PERFORMANCE OBJECTIVE

(Stimulus)	On request from supervisor
(Behavior)	The NMT will perform imaging procedures on a patient to produce an image demonstrating the distribution of a radiopharmaceutical throughout the brain
(Conditions)	With indirect supervision; using rectilinear scanners or gamma-ray camera at various times following administration of any one of several radiopharmaceuticals which may be prescribed by the nuclear physician, e.g., Tc-99m as pertechnetate, I-131 HSA, Yb-169, In-111, DTPA
(Criteria)	Review by the supervisor verifies that image is technically satisfactory with sufficient anatomic detail and photographic density to provide useful clinical information for diagnostic evaluation
(Consequence)	A two-dimensional film image of diagnostic quality is obtained which is representative of the distribution of radiopharmaceutical within the brain
(Next Action)	Repeat views or take additional views as requested by nuclear physician. When study is signified complete by nuclear physician, file film for conference or for nuclear physician's assessment, and report

KNOWLEDGES AND SKILLS

Theory and use of rectilinear scanner, gamma-ray camera system
Proper collimators and techniques for use of various brain scanning agents, e.g., Tc-99m, Yb-169, In-111, I-131 HSA, DTPA
Topographic anatomy of brain and skull
Dosage of complementary drugs which may sometimes be administered by technician with direct supervision by the nuclear physician, e.g., $KClO_4$, atropine, Lugol's solution
Film processing techniques
Methods of restraining patient
Handling of unconscious/incompetent/pediatric patient

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XVI: Central Nervous System Studies

MODULE 3: CISTERNOGRAPHY SCAN

TASKS a. Perform cisternography scan

PERFORMANCE OBJECTIVE

(Stimulus)	On request from supervisor
(Behavior)	At stated time intervals following intrathecal administration of a radiopharmaceutical by the physician, the NMT will perform imaging studies on a patient to visualize the pathways of cerebrospinal fluid movement
(Conditions)	With indirect supervision; according to local standard operating procedures (U.S. Navy manual); using a rectilinear scanner or gamma-ray camera, radiopharmaceutical administered by the nuclear physician, e.g., Tc-99m, Yb-169, I-131 HSA
(Criteria)	Review of images by the nuclear physician at each stage of the study verifies that studies are technically satisfactory
(Consequence)	The time course of movement and normal and/or abnormal pathways of cerebrospinal fluid movement are determined, providing information of value in the diagnostic process
(Next Action)	File film for conference or nuclear physician's assessment and report

KNOWLEDGES AND SKILLS

Theory and use of rectilinear scanner, gamma-ray camera
Proper collimator for various agents which may be used, e.g., Tc-99m, Yb-169, I-131
Anatomy of the brain and cerebrospinal fluid pathways
Dosage and form of complementary drugs which may sometimes be administered by NMT with direct supervision by the nuclear physician, e.g., Lugol's solution (saturated solution of KI)
Film processing
Handling of unconscious/incompetent/pediatric patient
Proper methods of restraint of patient

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XVI: Central Nervous System Studies

MODULE 4: CEREBROSPINAL FLUID LEAKAGE TEST

TASKS a. Perform cerebrospinal fluid leakage test

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request of supervisor
(Behavior)	The NMT will perform tests on fluid collected from the nostrils or auditory canals of a patient to determine the fraction of an administered dose of radiopharmaceutical which appears in the nasal fluid or in the external auditory meati
(Conditions)	With indirect supervision; according to standard laboratory technique (U.S. Navy manual); using well-type scintillation counter, standard representative of dose of Tc-99m given to patient, cotton swabs to collect fluid from nares and/or ears
(Criteria)	Technical review by the supervisor verifies that results provide useful information for diagnostic evaluation
(Consequence)	An indication of abnormal loss of cerebrospinal fluid is obtained, providing data for diagnosis of the patient's condition
(Next Action)	Record and report results

KNOWLEDGES AND SKILLS

Safe handling procedures for radioactive materials
Use of well-type scintillation counters
Statistics of low-level counting
Calculations of fractional activity recovered in a sample compared to administered dose

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT XVII: RETICULOENDOTHELIAL SYSTEM STUDIES

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XVII: Reticuloendothelial System Studies

MODULE 1: LIVER SCAN

TASKS

a. Perform liver scan for reticuloendothelial system function

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request of supervisor
(Behavior)	The NMT will perform imaging studies of the patient's upper abdomen from various angles to determine the functional anatomical configuration of the liver
(Conditions)	With indirect supervision; according to local standard procedures (U.S. Navy manual); using either rectilinear scanner or gamma-ray camera and radiopharmaceutical prescribed by the nuclear physician, e.g., colloidal Au-198, Tc-S colloid, I-131 microaggregates
(Criteria)	Review by the supervisor verifies that an image is technically satisfactory with sufficient anatomic detail and photographic density that it provides useful clinical information
(Consequence)	An image or series of images of the distribution of a radiopharmaceutical throughout the reticuloendothelial system of the liver is obtained, providing information for a correct diagnosis of the functional status of the patient's liver by the nuclear physician
(Next Action)	File films for conference, report and record results after this

KNOWLEDGES AND SKILLS

Use and operating parameters of rectilinear scanner and gamma-ray camera for all of the various radiopharmaceuticals which may be used for this test, e.g., Tc-99m, I-131, Au-198
Safe handling of radioactive materials
Film processing
Venipuncture techniques
Administration of I.V. radiopharmaceutical with direct supervision by the nuclear physician
Gross anatomy of the liver, gall bladder, spleen, heart
Optimal times for scanning (post-administration of dose)

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XVII: Reticuloendothelial System Studies

MODULE 2: SPLEEN SCAN

TASKS a. Perform spleen scan

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request of supervisor
(Behavior)	The NMT will perform imaging studies of the patient's left upper abdomen from various angles to determine the anatomical configuration of the patient's spleen
(Conditions)	With indirect supervision; according to local standard procedures (U.S. Navy manual); using either rectilinear scanner or gamma-ray camera, and the radiopharmaceutical prescribed by the nuclear physician, e.g., Tc-S colloid
(Criteria)	Review by the supervisor verifies that the image is technically satisfactory with sufficient anatomic detail and photographic density that it provides information of clinical value
(Consequence)	One or more images of the distribution of a radiopharmaceutical throughout the spleen is obtained, from which the nuclear physician may determine the spleen's size and shape, aiding him in diagnosing various hematologic conditions
(Next Action)	File film for conference, report and record results after this

KNOWLEDGES AND SKILLS

Use and operating parameters (including collimators) of rectilinear scanner and gamma-ray camera for all of the various radiopharmaceuticals which may be used for spleen imaging
Safe handling of radioactive materials
Film processing
Venipuncture technique
Administration of I.V. radiopharmaceutical with direct supervision by the nuclear physician
Gross anatomy of the upper abdomen
Optimum time (post-dose) for imaging studies

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XVII: Reticuloendothelial System Studies

MODULE 3: BONE MARROW SCAN

TASKS a. Perform bone marrow scan

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request from supervisor
(Behavior)	The NMT will perform imaging studies sufficient to determine the distribution of an administered radiopharmaceutical throughout all or part of the patient's bone marrow
(Conditions)	With indirect supervision; according to local standard operating procedures (U.S. Navy manual); using gamma-ray camera, single or dual rectilinear scanner, radiopharmaceutical prescribed by nuclear physician, e.g., Tc-S colloid, colloid Au-198
(Criteria)	Review by supervisor verifies that images are of technically satisfactory quality, with sufficient anatomic detail and photographic density that they provide useful clinical information for diagnostic evaluation
(Consequence)	An image or series of images of the bone marrow is obtained, indicating the distribution of a radiopharmaceutical throughout the bone marrow, and aiding the nuclear physician in diagnosing various hematologic and cancerous conditions
(Next Action)	File images for conference, after that report and record results as dictated by nuclear physician

KNOWLEDGES AND SKILLS

- Use and operating parameters of gamma-ray camera, single- and dual-head rectilinear scanner
- Minification system for imaging
- Safe handling of radioactive materials
- Film processing
- Venipuncture techniques
- Administration of I.V. dose with direct supervision by nuclear physician
- Various radiopharmaceuticals which may be used for bone scanning and the instrument operating parameters (including collimators) which must be used with each, e.g., Tc-S colloid, Au-198 colloid
- Optimum time from injection to imaging study

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT XVIII: METABOLIC STUDIES

This unit includes the following module:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XVIII: Metabolic Studies

MODULE 1: ALBUMIN TURNOVER STUDIES

TASKS a. Perform albumin turnover studies

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request from supervisor
(Behavior)	The NMT will perform tests (serial sampling and assay of the activity in the patient's serum) sufficient to determine the rate of turnover or renewal rate of serum albumin in the patient's system
(Conditions)	With indirect supervision; in accordance with local standard procedures (U.S. Navy manual); using aseptic techniques, radioactive iodinated serum albumin, syringes, pipettes, well-type scintillation counter
(Criteria)	Technical review by the supervisor verifies that test has been done in a technically satisfactory manner, providing useful results for diagnostic evaluation
(Consequence)	An assessment is obtained of the rate of turnover and bodily stores of serum albumin
(Next Action)	Record and report results

KNOWLEDGES AND SKILLS

Safe handling and use of radioactive iodinated serum albumin
Aseptic technique
Venipuncture technique
Methods to determine activity of administered radionuclides
Graphing data on semi-log paper
Calculations necessary to determine pool size and rate of turnover of albumin in patient
Use of centrifuge
Calculation of extracellular fluid volume

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT XIX: FERROKINETIC STUDIES

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XIX: Ferrokinetic Studies

MODULE 1: FERROKINETIC STUDIES

TASKS

a. Determine total iron-binding capacity
b. Determine serum iron clearance
c. Determine plasma iron turnover rate
d. Determine red cell iron utilization

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request of supervisor
(Behavior)	The NMT will perform tests sufficient to determine the patient's ability to clear, bind and utilize exogenous radioactive iron
(Conditions)	With indirect supervision; in accordance with local laboratory routine (U.S. Navy manual); using aseptic technique, radioactive iron, syringes, pipettes, anticoagulants, well-type scintillation counter, single-channel analyzer
(Criteria)	Technical review by supervisor verifies that tests have been performed in a technically satisfactory manner, providing useful results
(Consequence)	An assessment of the status of the patient's bodily iron stores and their rate of utilization, providing data for diagnosis of the cause of patient's anemia
(Next Action)	Record and report results

KNOWLEDGES AND SKILLS

Safe handling and use of radioactive iron
Venipuncture technique
Aseptic technique
Methods to determine activity of administered radionuclide
Hematocrit determination
Iron metabolism
Graphing data on semi-log and linear paper
Calculations necessary to determine rate of turnover of iron in plasma
Calculation of blood and plasma volume from standard and sample counting rates
Techniques of storing blood and plasma samples for subsequent counting
Specific activity
Use of centrifuge for separation of plasma from red cells

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XIX: Ferrokinetic Studies

MODULE 2: IRON ABSORPTION STUDY

TASKS a. Perform oral 59-Fe absorption study

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request from supervisor
(Behavior)	The NMT will perform tests to determine the fraction of an orally administered dose of iron-59 absorbed from the gastrointestinal tract
(Conditions)	With indirect supervision; in accordance with local laboratory routine (U.S. Navy manual); using radioactive iron, probe-type radiation detector, gamma-scintillation type detector
(Criteria)	Technical review by the supervisor verifies that the test has been performed in a technically satisfactory manner, providing useful results
(Consequence)	An estimate is obtained of the patient's ability to absorb dietary iron from the gastrointestinal tract, providing data for a correct diagnosis for the patient's anemia
(Next Action)	Report and record results

KNOWLEDGES AND SKILLS

Safe handling and use of radioactive iron
Methods to determine activity of administered dose or radioactive iron
Calculations necessary to determine amount of iron-59 recovered in stool specimen from standard and sample count rates
Counting techniques for large volume samples
Collection, preservation and mixing methods for samples of stool, collected without contamination by urine
Effects of quantity of orally administered iron on percent absorption
Specific activity of non-carrier free iron-59

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XIX: Ferrokinetic Studies

MODULE 3: IRON ORGAN COUNT

TASKS a. Determine organ external count rate ratios by radioisotopic technique

PERFORMANCE OBJECTIVE

(Stimulus)	Upon request of supervisor
(Behavior)	The NMT will perform tests on the patient to determine the relative counting rate over organs containing iron-59, e.g., liver, spleen, active bone marrow
(Conditions)	With indirect supervision; in accordance with local laboratory procedures (U.S. Navy manual); using probe-type gamma scintillation counter, collimator, single-channel analyzer
(Criteria)	Technical review by the supervisor verifies that tests have been performed in a satisfactory manner, leading to useful results
(Consequence)	An assessment of the degree of concentration of radioactive iron in body storage areas is obtained, providing information for diagnosis of the patient's disease state
(Next Action)	Report and record results

KNOWLEDGES AND SKILLS

Theory and use of gamma-ray spectrometer (single-channel analyzer)
Metabolism of iron
Topographical anatomy of liver, spleen, bone marrow
Methods for correcting for radioactive decay and biologic elimination of Fe-59 from patient
Interaction of radiation with matter, especially absorption and scatter
Use of single-channal analyzer to count higher energy gamma rays in presence of lower energy rays
Calculation of ratios of counting rates in various organ combinations
Data plotting on linear graph paper

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

COMPETENCY UNIT XX: NUCLEAR MEDICINE CLINICAL ADMINISTRATION

This unit includes the following modules:

Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XX: Nuclear Medicine Clinical Administration

MODULE 1: MAINTENANCE OF LABORATORY REPORTS AND DATA

TASKS

a. Assign scan identification number
b. Copy scans
c. File scans
d. Check scans out to the wards or physicians
e. Assess completeness of laboratory reports
f. Arrange for/follow up completion of clinical laboratory test
g. Log specimens sent/received
h. Maintain log of results of sterility and pyrogen testing
i. Send reports of laboratory results
j. Maintain log of radioisotope studies

PERFORMANCE OBJECTIVE

(Stimulus)	Routinely or on supervisor's request
(Behavior)	The NMT will assign code numbers to scans, copy, file and check out scans; arrange for follow-up of studies and maintain logs for specimens and study results
(Conditions)	With indirect supervision
(Criteria)	Performed in accordance with standard laboratory procedures; judged satisfactory upon review by supervisor
(Consequence)	Properly maintained records facilitating efficient retrieval of information contained in diagnostic studies
(Next Action)	Record results of properly completed study; schedule patient for restudy or alternative studies when necessary

KNOWLEDGES AND SKILLS

Use of interrogation form and/or laboratory check list of conditions which contraindicate performance of the test or its modification
Principles and procedures of all tests performed in the laboratory and techniques to communicate this information to patient in layman's terms
Methods for collecting uncontaminated samples of feces and urine
Medical ethics, confidentiality of privileged information

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Competency: NUCLEAR MEDICINE TECHNICIAN (NMT)

Unit XX: Nuclear Medicine Clinical Administration

MODULE 2: RADIOPHARMACEUTICAL INVENTORY

TASKS

a. Record receipt and issue of radiopharmaceuticals
b. Maintain records of receipt/transfer of radioactive material
c. Store radiopharmaceuticals
d. Prepare patient radiopharmaceutical dose record
e. Ship/transport radiochemical compounds to other labs for testing
f. Remove expired radiopharmaceuticals from active inventory

PERFORMANCE OBJECTIVE

(Stimulus) Routinely or upon supervisor's order

(Behavior) The NMT will maintain current inventory files of radioactive materials received, on hand, used or otherwise disposed of, and arrange for storage of these materials

(Conditions) With indirect supervision

(Criteria) Inventories maintained in accordance with conditions stated in AEC license for use of by-product materials, standard hospital procedure, and BuMed Radiation Protection Guidelines, AEC, 10CFR20 and DOT regulations

(Consequence) By-product materials maintained under strict surveillance at all times resulting in their use only in accordance with AEC license conditions

(Next Action) Report inventory results to supervisor and/or local radiation control office on a routine basis

KNOWLEDGES AND SKILLS

Principles and practice of inventory maintenance
Hospital, BuMed and AEC regulations relating to use, storage and disposal of by-product materials
Use of slide rule, calculations, decay table and/or graphs
Use of area radiation monitoring equipment, e.g., Geiger-Müller counter and ionization chambers
Use of radionuclide standardization equipment, e.g., re-entrant type ionization chamber and well-type scintillation counters
Shielding methods and allowable radiation exposure levels for radiation workers and the general public